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NEAR FIELD PATTERN ANALYSIS FOR APERTURE OR MONOPOLE ANTENNAS M--ETC(U)
JAN 78 E L PELTON, N WANG, W D BURNSIDE N00019-77-C-0299
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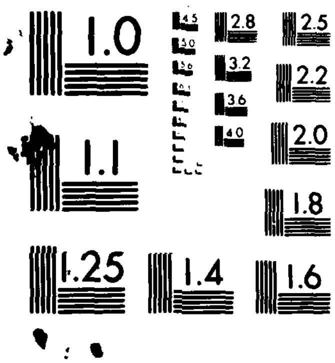

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ABSTRACT

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I. INTRODUCTION

During the previous two quarters analyses were presented for 1) computing the near fields of a short magnetic dipole mounted on an elliptic cylinder[1] and 2) computing the edge diffraction point in the near field for a finite flat plate used in conjunction with the elliptic cylinder[2]. Within the context of the overall problem of studying the near field effects of on-aircraft antennas, it may be recalled that the elliptic cylinder and plates are being used to model the aircraft fuselage and wings, respectively. Since the short magnetic dipole (i.e., a short slot) previously used in conjunction with the elliptic cylinder has a rather limited practical applicability, the first task carried out during the present quarter was to expand the types of antennas which can be treated. Presently, an analysis has been developed for computing the near-fields of an arbitrary length monopole or a finite rectangular aperture antenna mounted on the elliptic cylinder. The rectangular aperture can be arbitrarily oriented on the surface of the elliptic cylinder. Computer programs, based on the new analysis, have been written and some of the initial results obtained with the programs are presented in Section II.

The central task of formulating an overall analysis for computing near field roll and elevation plane patterns of on-aircraft antennas has also been carried out during the present quarter. A general computer code, based on the overall analysis, has been written. A brief description of the new solution, along with some initial comparisons between measured and numerically computed near field patterns, is presented in Section III. The computed solutions can accommodate receiver range specifications varying from as close as one wavelength to the aircraft surface to the true far field.

In achieving a suitable design for an on-aircraft antenna system, the capability to specify the receiver range is a very useful feature of the new solution. Specifically, an essential step in the design procedure typically involves establishing close agreement between numerically computed results and measurements taken on an actual or scale model aircraft. Previous numerical solutions have been able to compute far field patterns only, and an inherent source of error has been present when comparing computed solutions with measurements in that measured aircraft pattern data are seldom obtainable under true far-field conditions. With the present solution this error can be eliminated, since the receiver range can be specified to precisely watch that of the measured data. Further, after the crucial checks between computations and measurements have been made, the numerical solution can be employed to predict the far field performance of the on-aircraft antenna system. The validity of the far field computed data is assured since the mechanisms involved in obtaining the numerical solution are the same in both the near and far field.

II. SAMPLE NEAR FIELD SOLUTIONS FOR APERTURE AND MONOPOLE ANTENNAS MOUNTED ON A CYLINDER

This section presents some sample pattern computations obtained with the newly developed analysis for computing the near fields of arbitrary length monopole and finite aperture antennas mounted on a general convex cylinder. (The detailed analysis for these solutions will be presented in the Final Report.) As an initial test of the new solution the measured and computed principal plane patterns of a $\lambda/4$ long monopole mounted on a 5" diameter circular cylinder were compared for a receiver range of 18" and a signal frequency of 9 GHz. These results are shown in Figure 1. As depicted in the insert of Figure 1, the signal was $\hat{\phi}$-polarized. Also, a small pyramidal horn was used as the receiving antenna for the near field measured pattern data shown.

In order to test the new solution for aperture type antennas, the patterns of axial and circumferential x-band waveguides (i.e., a 0.4" by 0.9" aperture) flush mounted in a 5" diameter circular cylinder were computed. Again, a receiver range of 18" and a signal frequency of 9

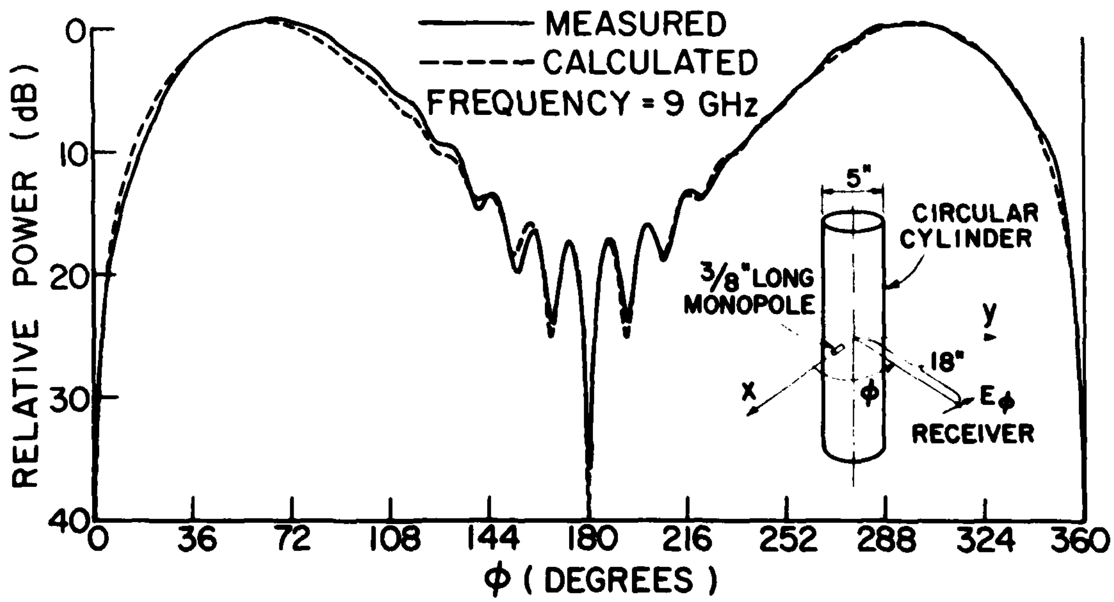
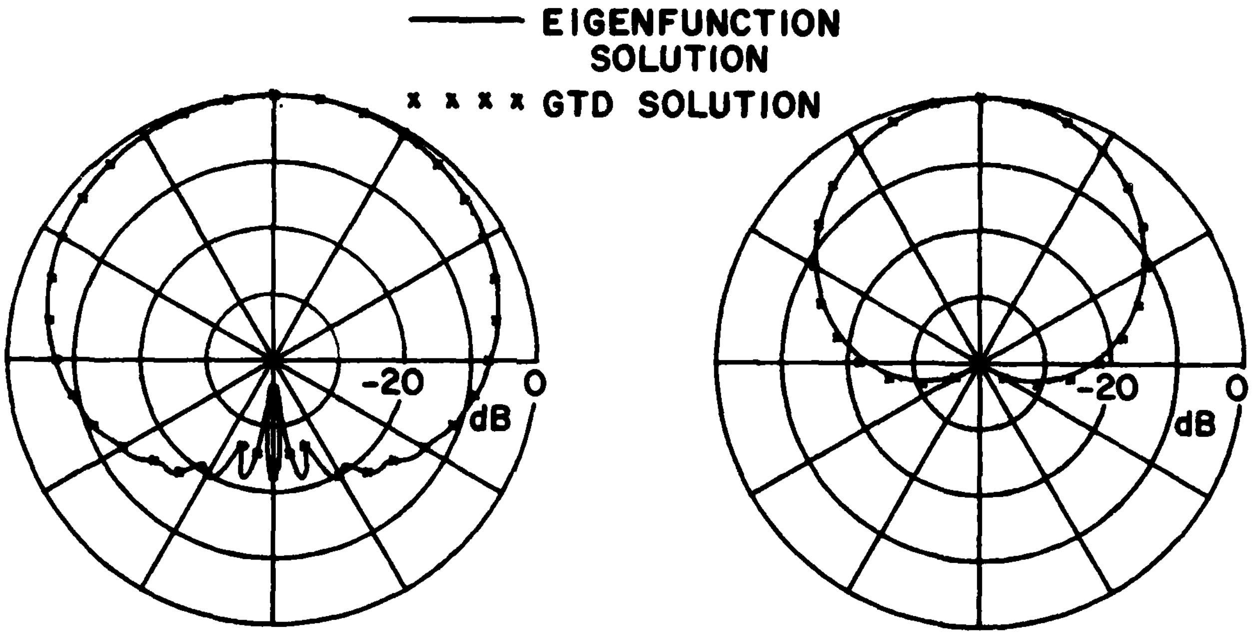


Figure 1. Comparison of measured and calculated near-field patterns for a $\lambda/4$ monopole on a circular cylinder. The receiver range is 18" for the data shown.

GHz were employed. Due to the complexity of constructing these geometries, the new solutions were compared with highly accurate eigenfunction solutions rather than with measurements. The results obtained are shown in Figure 2. The signal is $\hat{\phi}$-polarized for the axially mounted waveguide patterns of Figure 2a and $\hat{\theta}$-polarized for the circumferentially mounted waveguide patterns of Figure 2b.



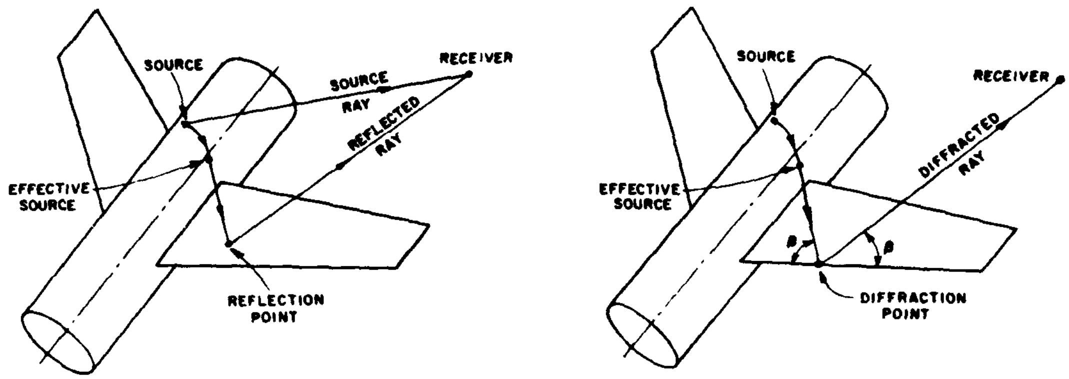
(a) axial waveguide

(b) circumferential waveguide

Figure 2. Normalized near zone electric field radiated by an open-ended x-band waveguide on a circular cylinder at a frequency of 9 GHz.

III. SOLUTION FOR THE NEAR-ZONE FIELDS OF AN AIRCRAFT MOUNTED ANTENNA

The first step in the solution consists of establishing suitable approximate models for analytical treatment of the aircraft structure. Previous far-field studies have shown that the aircraft fuselage can be adequately modeled by an elliptic cylinder of appropriate shape and that finite flat plates are suitable to model wings, vertical stabilizers and other features of the aircraft structure[3]. This same approach for modeling the aircraft structure is employed in the present analysis. A typical analytical model of the aircraft structure, suitable for roll-plane pattern computations, is depicted in Figure 3. For simplicity, the aircraft model shown depicts only the wings and fuselage. Additional plates may be added to model stabilizers. Also, analytical models of the aircraft structure suitable for elevation plane pattern



(a) (b)

Figure 3. Typical roll plane models used to simulate an aircraft structure, with rays used to depict various field components. Part (a) depicts rays for the direct and reflected fields, and (b) shows rays for the edge diffracted fields.

calculations can readily be constructed as has been done in previous far-field studies[3]. Finally, in the following discussion the antenna is a flush-mounted aperture or monopole antenna which is mounted on the fuselage and located at least a wavelength from the nearest plate.

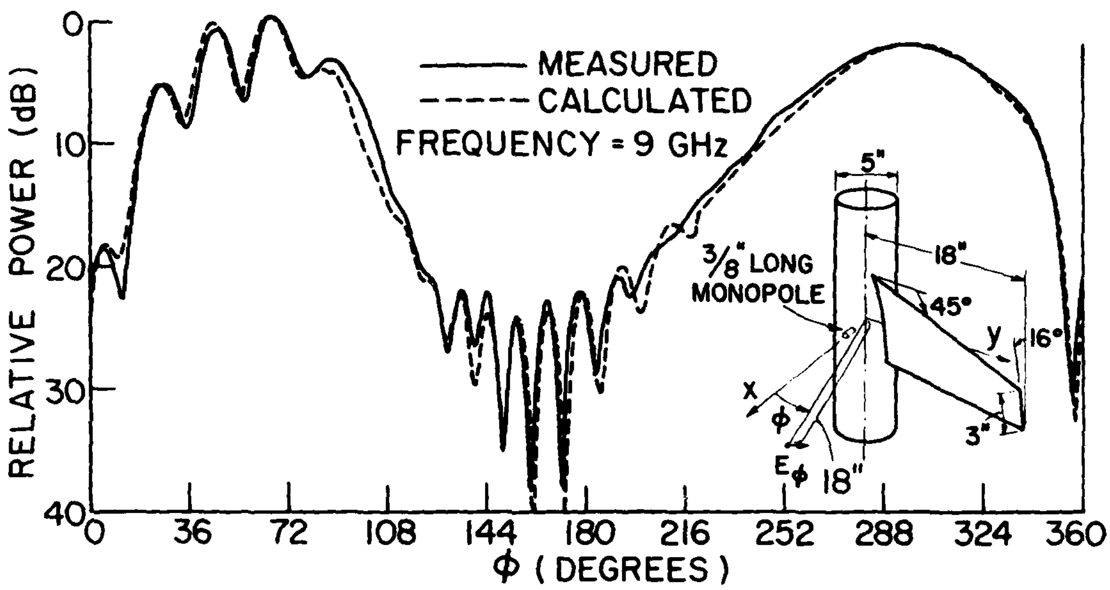
Using aircraft models as depicted in Figure 3, the computed solutions are obtained by superposition of the following field components: 1) direct field from the source; 2) curved surface diffracted fields from the generalized elliptic cylinder; 3) reflected fields from the surfaces of the finite flat plate wings and stabilizers; 4) diffracted fields from the edges of the plates, including diffraction from the curved junction edges formed by the intersection of the plates with the elliptic cylinder; and 5) tip diffraction from the corners of the finite plates. The solution includes or excludes field terms depending upon the receiver location. In treating plate scattering, the solution also predicts blockages by other plates or the elliptic cylinder and excludes blocked reflected and diffracted rays, as appropriate, for any specified receiver location.

The GTD analysis incorporates newly formulated integral representations expressed in terms of the Fock functions[1] for computing the near-zone fields throughout the entire space surrounding the cylinder, including computation of the field at points of reflection and diffraction as depicted in Figures 3a and 3b, respectively. In computing the reflected fields ray optics and image principles are used to determine the reflection point location within the physical

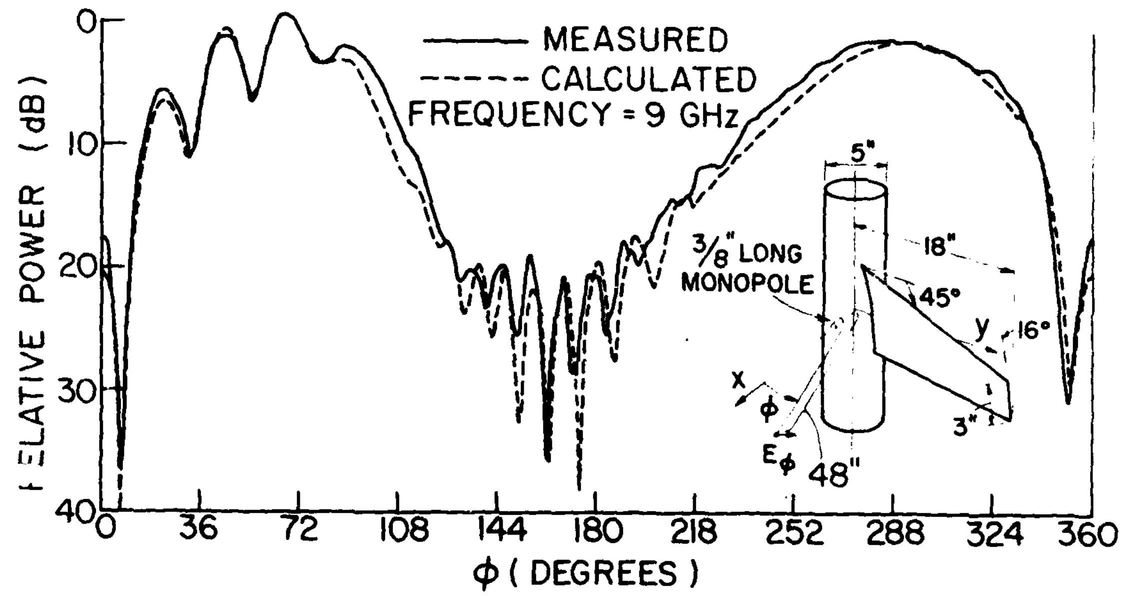
bounds of the finite plate surfaces. The solution for the near-zone fields diffracted from the edges of the finite plates incorporates the recently developed near-field analysis for determining the location of the diffraction point[2]. Use of this analysis permits efficient calculation of the fields diffracted from all plate edges including the curved junction edges where the plates attach to the elliptic cylinder at an angle with respect to the cylinder axis.

As noted earlier, a computer code based on the GTD analysis has been written to compute the near field pattern effects of on-aircraft antennas. The calculated and measured data shown in Figures 4-6 offer a sampling of the results obtained to date with the new near-field analysis. Figure 4 shows a comparison between measured and calculated patterns for a test geometry composed of a monopole on a circular cylinder with one attached plate. As indicated, the plane of the plate is tilted 16° with respect to the cylinder axis so that a curved edge exists at the plate cylinder junction. The planar patterns shown in parts a and b of Figure 4 were obtained with the receiver located 18" and 48" from the cylinder axis, respectively. Figure 5 shows computed patterns of the same test geometry for receiver ranges of 18", 48" and 500". The peak signal levels for all three patterns have been set equal to demonstrate the relative effects of receiver range. The pattern computed at a range of 500" is essentially a far-field pattern for the 9 GHz frequency employed.

A practical final example demonstrating the improved results obtainable with the near-field analysis is depicted in Figure 6, which compares measured and calculated elevation plane patterns for a monopole antenna mounted over the cockpit of a Boeing 737 aircraft. The measured data shown were taken in an anechoic chamber using a highly detailed 1/11 scale model aircraft[3]. The receiver range used for the measured data was 26 feet. (This is equivalent to a range of 290 feet on a full scale 737 aircraft.) Two computed patterns are also shown in Figure 6 for comparison. One of the computed patterns was obtained from a previously developed far-field analysis[3] while the other was obtained using the present near-field analysis. Both of the computed solutions employ the same cylinder and plates model (depicted in the insert) to simulate the aircraft structure, and comparable scattering terms are included in both solutions. The present near-field solution, of course, employs the same receiver range as the measured data. The improved results obtained with the present analysis are especially apparent in the lower-left quadrant of the patterns of Figure 6.



(a)



(b)

Figure 4. Comparison of measured and calculated near field patterns for a test geometry composed of a circular cylinder and one plate. The receiver range is 18" for the data shown in part a) and 48" in part b).

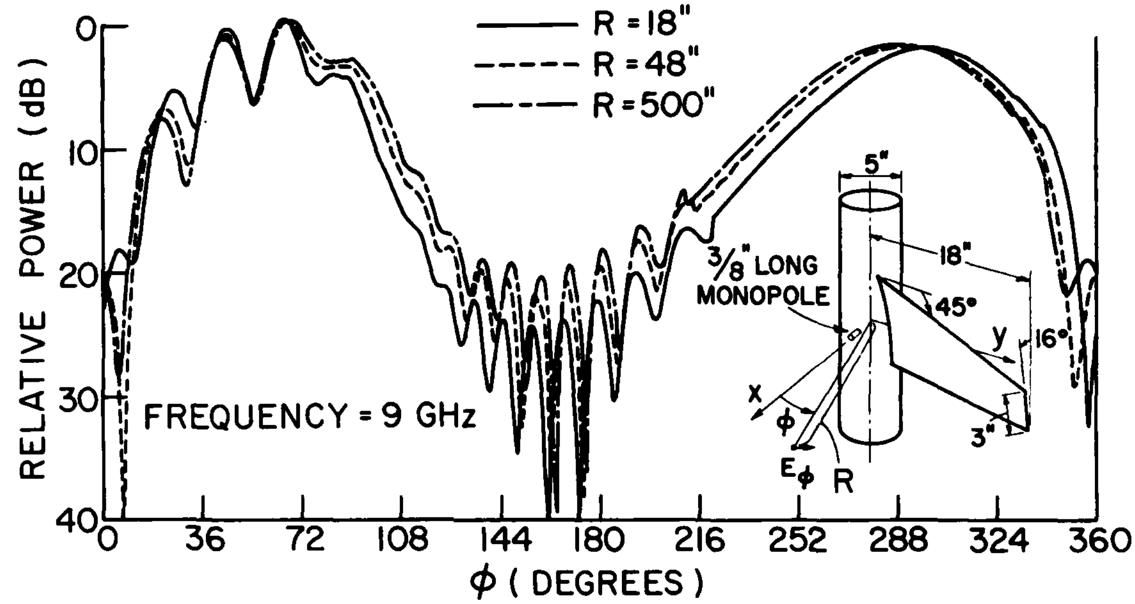


Figure 5. Comparison of calculated patterns of the indicated test geometry for receiver range values of 18", 48" and 500". The peak-signal levels have been set equal to aid comparison of overall pattern shape.

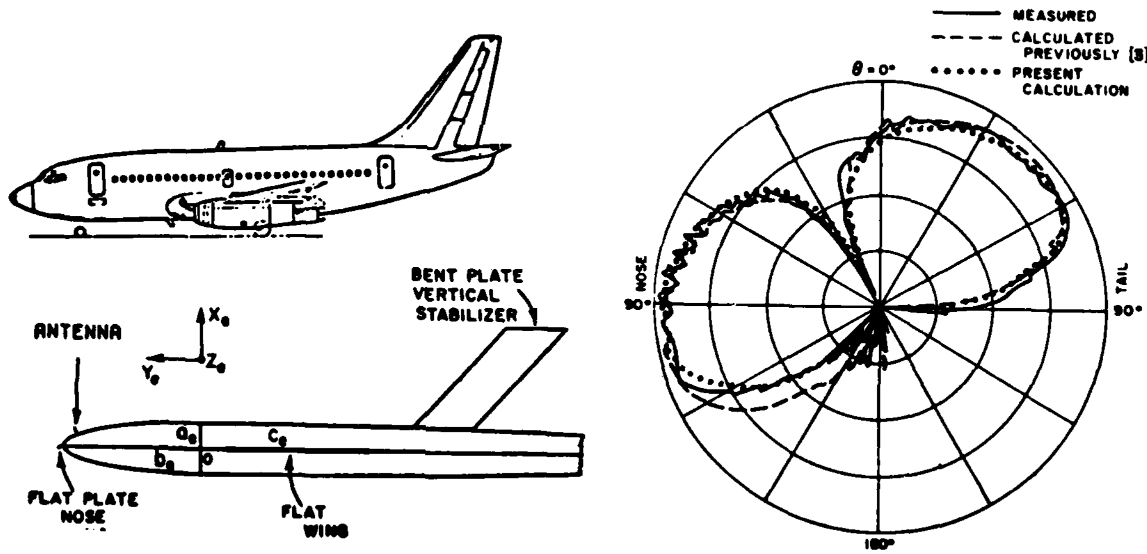


Figure 6. Comparison of measured and calculated elevation plane patterns of a monopole antenna mounted on a Boeing 737 aircraft. The insert at the left shows profile views of the actual aircraft, and the approximate analytical aircraft model used in the computed results.

IV. SUMMARY

In the present quarter an analysis was developed for treating an expanded class of on-aircraft antenna types. The fuselage mounted antennas which can be modeled analytically in the near field include arbitrary length monopoles and flush-mounted rectangular aperture antennas. The aperture antennas can be arbitrarily oriented on the surface of the generalized elliptic cylinder model of the aircraft fuselage. Near field pattern data demonstrating the excellent results obtainable with the new analysis were shown in Figures 1 and 2.

An overall analysis for computing principal plane patterns of antennas on aircraft in the near field was also formulated during the present quarter. The solution is based on the Geometrical Theory of Diffraction and can be used to compute principal plane on-aircraft antenna patterns for any receiver range, including ranges as close as one wavelength to the aircraft surface. Finally, a general computer code based on the new solution has been written to provide for efficient numerical computation of the near field of on-aircraft antennas. Some of the initial computed patterns obtained with the program were presented in Figure 4-6. The patterns of Figure 6, for a monopole antenna mounted over the cockpit of a Boeing 737, provide a specific practical example of the improved results obtainable with the present solution compared with previously developed far field solutions.

During the next quarter the full capabilities of the new solution will be established. Specifically, based on knowledge of previous studies, it is anticipated that the present solution can be applied to accurately predict pattern performance in planes other than the principal (i.e., roll and elevation) planes. It is planned to verify this by comparing measured and computed conical patterns of the test geometry depicted in Figure 3. Also, additional comparisons with available measured on-aircraft data (such as that shown in Figure 6) will be made.

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